MERCURY CONTAMINATION IN GEORGIA RAILS

by

Ron R. Odom

Georgia Department of Natural Resources

Game and Fish Division

Social Circle, Georgia

ABSTRACT

Ninety-four specimens of rail, crab, and snail, collected at ten separate locations along the Georgia Coast between October, 1971, and September, 1973, were analysed for residual mercury.

Excessive concentrations of mercury were found in specimens of clapper rail, sora, and periwinkle snail, collected from the Brunswick and Savannah estuaries. Actual concentrations within these two river systems ranged from 0.11 ppm. in one sample of sora breast muscle to 16.8 ppm. in periwinkle snail tissue (fresh wet weight basis).

Mercury contamination exceeded the F.D.A. tolerance level of 0.50 ppm. in all clapper rail breast muscle samples taken from the Brunswick estuary, west of the Highway #17 bridge.

Analysis of specimens taken outside of the Brunswick and Savannah estuaries indicated varying degrees of contamination, particularly in rails, although still well below the F.D.A. limit.

INTRODUCTION

The Turtle River-Brunswick River Area, upstream from Brunswick, Georgia; and the Savannah River, from Augusta to Savannah River, from Augusta to Savannah, were identified in 1970 and 1971 as being heavily contaminated with mercury, discharged for many years by the chloro-alkalai industry along the rivers. The Olin Corporation and the Allied Chemical Corporation were singled out as the primary mercury polluters in the Savannah River and Brunswick estuary (Georgia Water Quality Control Board 1971). Both are typical mercury-cell type chloro-alkalai plants which manufacture chlorine and caustic soda, through electrolysis of brine by using mercury as an electrode.

In 1970, Allied and Olin discharged 3 and 10 pounds per day respectively into adjacent waters. Discharges in both plants have now been reduced to less than 0.25 pounds per day (Georgia Water Quality Control Board 1971).

In the Brunswick estuary, mercury contamination generally was found to be greater than the 0.50 ppm. limit, as set by the U.S. Food and Drug Administration, in the blue crab (*Callinectes sapidus*), speckled trout (*Cynoscion nebulosus*), and flounder (*Paralichthys lethostigma*). Subsequently the State Game and Fish Division banned all fishing and crabbing in the Brunswick estuary and in the Savannah River, from Augusta to Savannah. Later, as concentrations of mercury in aquatic samples decreased, the ban on fishing and crabbing was lifted. In 1973, the State Department of Natural Resources and the Environmental Protection Agency issued a warning to hunters not to eat clapper rails taken upstream from the Highway #17 bridge in the Brunswick estuary due to the discovery of high mercury residues in the birds.

Sampling in 1970-71 was restricted to fish, crabs, shrimp, and shellfish with no attempt to monitor levels in marsh birds or mammals within the contaminated area, even though birds and mammals both were present in large numbers and were an integral part of the saltmarsh ecosystem.

Core samples taken in 1971 from the Brunswick estuary, revealed the presence of mercury in sediments to a minimum depth of 12 inches. Samples at depths greater than these were not taken (Zeller and Finger 1971).

The saltmarsh in the Brunswick estuary supports an extremely high population of clapper rail (*Rallus longirostrus*), which are hunted by a growing number of sportsmen each fall. Large numbers of soras (*Porzana carolina*) also use these same marshes during periods of migration, though seldom are they hunted.

Possible contamination, particularly of the potentially important clapper rail and its food chain, was suspected; therefore collections of rails and rail food items were initiated at various locations along the Georgia Coast. Of primary concern was levels of mercury present in the eatable portion of the marsh hen, which might be ingested by hunters.

The author would like to express his appreciation to Richard Gingrich of the Environmental Protection Agency who originally recognized the potential mercury problem in rails and initiated the 1971 collections. The Environmental Protection Agency Lab in Athens, and the State Environmental Protection Division Lab in Atlanta are to be thanked for the actual analysis of the specimens.

MATERIALS AND METHODS

A total of 62 individual rails, 12 snails, and 7 crabs were collected for analysis from ten different stations along the Georgia Coast between October, 1971 and September, 1973. A general map of the Study Area, indicating collection sites, is shown in Figure 1. Rail samples consisted of breast tissue, livers, feathers, beaks, egg contents, and egg shell, though not in equal numbers.

Most specimens were collected upstream from the Highway #17 bridge in the Turtle River-Brunswick River Area, which was known to be heavily polluted with mercury. Additional collections, in smaller numbers, were made at other locations between Brunswick and Savannah, including the outer fringe of the Savannah estuary.

Initial collections were made in the Turtle River Marsh, adjacent to the Allied Chemical Plant at Brunswick, in October, 1971. Six clapper rails and one sora were then collected during high tides with a shotgun. Three periwinkle snails (*Littorina* irrorata) and one fiddler crab (*Uca* sp.) were also collected. All of these original specimens were dissected on the same day, with samples of breast muscle and liver being taken from each. Each sample was wrapped and individually labeled, then immediately frozen prior to shipment to the lab in Atlanta. Data generated by this first small sample prompted additional sampling along the Georgia Coast.

The second sample was collected, as time permitted, between February 15, and September 3, 1973 at various locations along the Georgia Coast. This sample consisted of 49 clapper rail, 12 soras, 3 King rail (*Rallus elegans*), 1 Virginia rail (*Rallus limicola*), 6 periwinkle snails, 3 squareback crabs (*Sasarma reticulatum*), and 3 fiddler crabs.

All rails were collected either by shotgun during daylight hours, or by nightlighting on high tides using an airboat and a dip net. All specimens of rail, crabs, and snails were frozen upon return to the lab to be partially thawed and dissected at a later date. Specimens were dissected while still partially frozen to insure against water loss in the tissue. Duplicate samples were taken of all of the 1973 birds, however the workload at the Environmental Protection Division Lab permitted only analysis of breast muscle tissue of clapper rail, which they considered to be high priority due to the possible health hazard.

Samples of breast muscle and liver were taken, individually wrapped, labeled, and refrozen in preparation for shipment to the Atlanta labs. Each sample of snail and crab tissue consisted of meat taken from several specimens from the same area. Several additional samples of feather, beak, egg, shell, and eggs were also analysed.

Duplicate samples were desirable in order that two independent analyses could be made on each specimen, insuring accuracy of analysis. Duplicate samples were not taken of the 1971 sample which was analysed by the Environmental Protection Agency.

Both laboratories utilize the flameless atomic absorption method to determine mercury concentrations in the specimens (Georgia Water Quality Control Board 1971).

RESULTS AND DISCUSSION

Results of both 1971 and 1973 analysis are presented in Tables 1 and 2 (fresh wet weight basis). As were expected, the most highly contaminated specimens were taken from the marsh immediately adjacent to the Allied Plant on the Turtle River. Mercury

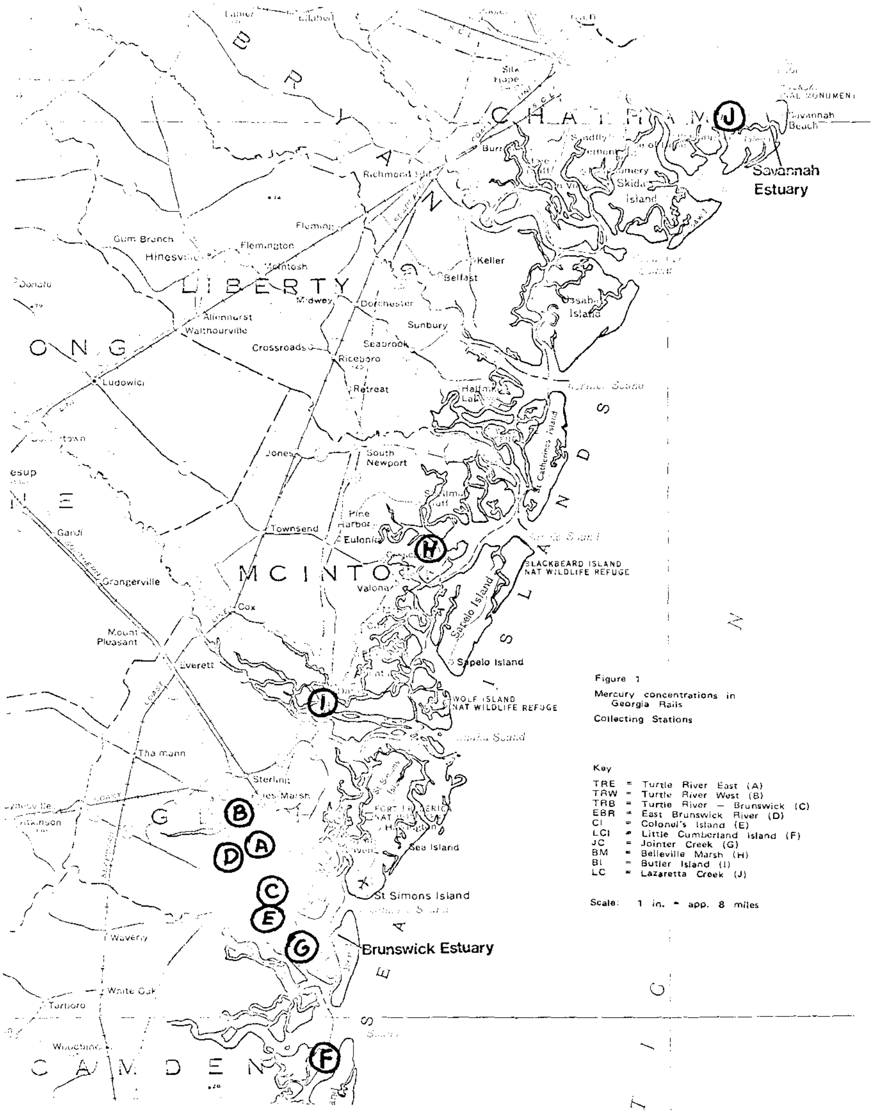

Figure 1

Mercury concentrations in Georgia Rails

Collecting Stations

contamination exceeded the 0.50 ppm. limit in all clapper rail breast muscle samples collected from the Brunswick estuary, both upstream and downstream from the source of pollution. In general, concentrations tended to decrease with distance from the chloro-alkalai plant. Twenty of thirty (67%) samples taken from the Turtle River contained concentrations in excess of 2.00 ppm., or four times the allowable limit for human consumption. Thirty-three percent had concentrations between 4.0 ppm. and 9.45 ppm.

Liver samples from this same group of clapper rail were correspondingly high. One feather had a mercury concentration of 30.3 ppm.

Many other species of birds occur along the Georgia Coast, and within the Brunswick and Savannah estuaries. It would be reasonable to assume that those species dependent on these contaminated marshes for survival are themselves contaminated to various degrees. Studies of similarly contaminated industrial areas in Canada found red-necked grebes (*Poediceps grisegena*), double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), common terns (*Mergus* serrator), and other species that were contaminated to various degrees (Fimreite, et al. 1971).

Reports of sick water birds are not uncommon in the Brunswick Area. Symptoms described, and in several instances observed, were similar to those characteristic of mercury poisoning. Symptoms appear to be neurological, including difficulty in walking and standing, and inability to control muscle movements. No recent necropsy records are available for water birds from the polluted area.

Borg (1969) found mercury concentrations in tissues of other fish-eating birds such as gulls (*Larus* sp.), cranes (*Grus grus*), and white-tailed eagles (*Haliaeetus albicilla*); and suggested that the decline in numbers of this species might well be associated with mercury contamination.

Waterfowl, mostly diving ducks, also utilize the estuaries. It is highly probable that waterfowl, using the polluted area, also contain elevated levels in their tissues; either picked up from the contaminated water, sediments, or from various contaminated invertebrates. Recent research has even suggested that plants (*Spartina alterniflora*) may concentrate mercury significantly to a degree above that in sediments (Windom 1972). Although not a preferred food, the seeds of cordgrass and black rush (*Juncus* roemerianus) are eaten by ducks and other song birds in coastal areas (Martin, Zim, Nelson 1951). Plants then, could play a significant role in contributing to the total mercury body burden.

Both polluted areas also support moderate to high mammal populations. Effects on such species as the mink (*Mustela vison*), raccoon (*Procycon lotor*), and otter (*Lutra* canadensis), which feed and thrive in and around the contaminated areas, have not been determined. High levels of mercury are also likely to have detrimental effects on mammal populations. Cats have been killed experimentally by feeding them fish and shellfish contaminated at 5.7 ppm. (Study Committee on Mercury Hazards 1970).

Levels of mercury were high in all samples of periwinkle snails taken from the Brunswick estuary. Twelve samples of snail tissue were analysed and ranged from a low of .71 ppm. to a high of 16.80 ppm. Average mercury content of these samples was 3.14 ppm. No samples of periwinkle snails were collected outside of the Brunswick area.

Oney (1954) found periwinkle snails to be an important component of the diet of the clapper rail on the Georgia Coast. Severe losses of the periwinkle population due to contamination would be certain to have adverse effects on clapper rail populations. Although, in Georgia, the clapper rail presently is not highly regarded as a gamebird, future demands may bring about a change in attitude.

Three samples of fiddler crabs and one of the square-back crab were taken from the Brunswick Area. All had mercury levels under the 0.50 ppm. limit.

Twelve soras, collected from the Brunswick Area, were heavily contaminated. Fifty-eight percent of these birds had mercury levels in excess of 0.50 ppm. in breast muscle tissue. The range of contamination was from 0.11 ppm. to 2.30 ppm., with an average of 0.90 ppm. One liver sample contained 12.08 ppm. - a level 24 times the maximum allowable limit. Although soras are even less important in Georgia as a gamebird than the marsh hen, they are hunted in some States and also may become increasingly popular in future years.

Large numbers of soras were observed using the Brunswick Area during migration. Even though these birds are not permanent residents of this area, they still contained high levels of mercury in their tissues. Since soras are primarily seed-eaters and are known to feed on cordgrass and spikerush (Martin et al. 1951), this would again suggest plants as a source of mercury. It is possible, since the mercury problem exists throughout the nation, that some of these birds could already contain elevated levels of mercury when they arrive in Georgia's marshes. Many States within the sora's breeding range have already documented mercury pollution problems (Subcommittee of the Commission on Government Operations 1971).

A significant number of clapper rail from the North Atlantic marshes are known to winter in Georgia marshes. Exact numbers are not known, however a number of banded marsh hens are recovered on the Georgia Coast by hunters each fall. It is possible that North Atlantic populations could be adversely affected by contaminated South Atlantic marshes.

Evidence of mercury contamination in the Savannah River Area showed up in a sample of 8 clapper rail taken from the Lazaretta Creek Area. Breast muscle from 4 of these 8 (50%) birds was found to be contaminated in excess of 0.50 ppm. Mercury levels from specimens in this area were not nearly as high as in specimens from the Brunswick Area. The particular area sampled, however, is not immediately adjacent to the Savannah River proper, which is known to be heavily polluted with mercury. This could account for the reduced levels which occurred. Windom (1972) found that mercury levels in sediments occurring adjacent to channels were consistently higher than levels away from the channel. The marshes directly along the river, adjacent to the river channel, undoubtedly would contain mercury levels comparable to those in the Turtle River Area. It is highly probable then, that rails and other animal life inhabiting the marshes adjacent to the river channel are contaminated and might possibly present a health hazard. Limited time and funding did not permit additional sampling of the Savannah River Area.

Additional sampling of wildlife in this area should be of immediate concern, because of human health hazards which might arise. The devastating effects on the human nervous system caused by the ingestion of excessive amounts of mercury have been vividly documented by others (Bakir, F. et al. 1973; Pierce, P. E., et al. 1972). Other studies have recommended monitoring of fish and crabs in the Savannah, Brunswick, and Turtle Rivers, until concentrations of mercury return to acceptable, safe levels (Georgia Water Quality Control Board 1971). I would further recommend that future sampling include all wildlife dependent upon these polluted marshes for their survival.

The remaining 10 clapper rail collected from relatively "clean" areas, were reasonably free of contamination. Only one specimen, collected off the tip of Colonel's Island, contained mercury in excess of 0.50 ppm. The other nine birds contained traces of mercury, although all were within acceptable limits. The average concentration in breast muscle tissue of this group was .34 ppm.

One sora collected from the "clean" area had a level of .40 ppm. in the liver. No analysis was made on the muscle tissue from this bird.

Three King rails (road kills) were collected on Butler Island, near Darien, Georgia. These three specimens contained surprisingly high levels of mercury in their flesh. Two of the birds would have been considered unsafe for human consumption with concentrations of 0.59 ppm. and 0.84 ppm., respectively. The Georgia Water Quality Control Board (1971) also found concentrations in excess on 0.50 ppm. in a few fish taken from waters receiving no known mercury discharge. Subtle sources of mercury were thought to be responsible such as: weathering of rock, fallout from air pollution, run-off from areas where mercury treated seeds had been used, and numerous other sources.

One Virginia rail (road kill) was collected from Butler Island and analysed. Mercury levels again were higher than expected (0.40 ppm.), although still within established limits.

One fiddler crab and two square-back crab specimens were collected from the Butler Island Area and contained levels of 0.20, 0.23, and 0.12 ppm., respectively.

Additional work correlating mercury levels in feathers and eggs with that in muscle tissue appears to be warranted. The Study Group on Mercury Hazards (1970) found that the tendency for mercury to be deposited in growing feathers, claws, beaks, and other keratinous structures, is so strong that they will eventually contain nearly all the mercury. Studies in Ohio (unpublished data 1970) indicated a strong correlation between mercury content in breast tissue and feathers. Perfection of this technique would enable the continual monitoring of mercury levels without sacrificing individual birds.

In Georgia the rail resource is under-utilized and it is unlikely that anyone would consume enough contaminated rail meat to suffer noticeable ill effects. The possible human health hazard becomes realistic however, when the many other possible sources of mercury in the coastal areas are considered. Persons eating fish, shellfish, small mammals, and rails from these polluted areas are cause for concern however, since they could be regularly ingesting large quantities of mercury.

The question of whether contaminated rails in the Brunswick and Savannah estuaries represent a human hazard is debatable. It is important however, that investigators look beyond the human health implications of an environment grossly polluted with mercury. One must think not only in terms of what is toxic to humans, but also what levels are toxic to wildlife. Sub-lethal effects on animal populations are often difficult to observe until they approach terminal conditions and for this reason they often go unnoticed.

There is presently no evidence that Georgia rail populations have suffered any adverse effects from the high levels of mercury accumulated from contaminated marshes. Populations in these highly polluted areas appear to be thriving in spite of the pollution problem.

The potential threat to the well-being of rails and other marsh birds occurring in these estuaries however, is supported by studies of experimental birds, which have been shown to undergo adverse effects from mercury when fed levels comparable to that found in rail foods.

Levels of mercury as low as 0.50 ppm. in eggs have been shown to cause decreases in hatchability and in viability of young in certain species of birds (Fimreite 1971, Fyfe 1971). Other studies on captive birds and mammals indicate that acute toxicity of methyl mercury resulted from levels between 12-20 ppm. (Study Group on Mercury Hazards 1970).

Heinz (1974) found that levels of less than 0.50 ppm. of methyl mercury in the diet of mallards induced adverse effects on reproduction and behavior. The rail data reported are based on total mercury content rather than only methyl mercury however, since methyl mercury often comprises 99% of the mercury in animal tissue, the resulting data should be comparable (Study Group on Mercury Hazards 1970).

Fimreite and Karstad (1971) found that a steady diet of chicks, containing 7-10 ppm. of methyl mercury in their livers, was fatal to red-tailed hawks. Typical neurological signs of mercury poisoning were observed in hawks prior to death. Fimreite (1971) concluded that "hatchability, at least, can be affected among wild birds where they have access to treated grains."

Other studies along the Atlantic Coast do utilize the rail as a game bird resource. Some even feel the resource receives all the pressure it can stand (Gilchrist Pers. Comm.). According to a 1971 survey, all of the Coastal States in the Southeast, except Florida, recognize the existence of a mercury pollution problem within their State (Sub-committee of the Committee on Government Operations 1971). Many of the Southeastern States have issued warnings to commercial fishermen and sport hunters, and some have even closed certain areas to hunting and/or fishing (Lambou 1972). All of these States are rail States, many of which utilize the rail as a game-bird. Chances are if your State's mercury pollution problem extends into it's saltmarshes - you've also got a clapper rail problem. It is unlikely that mercury contamination in rails is a problem peculiar to the State of Georgia.

Table 1. Mercury Content in Georgia Rails (Fresh Wet Weight Basis).

			Hg. Concentration (ppm.)				
Date	I.D.#	Species	Breast Muscle	Liver	Other	Age	Location
10/71	1	Clapper Rail	3.49	6.00	–	A	TRE
10/71	2	Clapper Rail	4.00	2.06	–	A	TRE
10/71	3	Clapper Rail	2.43	8.63	–	A	TRE
10/71	4	Clapper Rail	1.56	3.83	–	A	TRE
10/71	5	Clapper Rail	1.42	3.95	–	A	TRE
10/71	6	Clapper Rail	4.67	7.82	–	A	TRE
6/30/73	7	Clapper Rail	4.20*	–	–	A	TRE
6/30/73	8	Clapper Rail	3.35*	–	–	A	TRE
6/30/73	9	Clapper Rail	4.90*	–	–	A	TRE
6/30/73	10	Clapper Rail	5.15*	–	–	A	TRE
6/30/73	11	Clapper Rail	5.00*	–	–	A	TRE
6/30/73	12	Clapper Rail	3.08*	–	–	A	TRE
6/30/73	13	Clapper Rail	3.45*	–	–	A	TRE
6/30/73	14	Clapper Rail	1.17*	–	–	4 wk.	TRE
6/30/73	15	Clapper Rail	2.89*	–	–	3	TRE
6/30/73	16	Clapper Rail	1.85*	–	–	1	TRE
6/30/73	17	Clapper Rail	2.00*	–	–	A	TRE
6/30/73	18	Clapper Rail	3.45*	–	–	A	TRE
6/30/73	19	Clapper Rail	3.25*	–	–	A	TRE
6/30/73	20	Clapper Rail	6.15*	–	–	A	TRE
6/30/73	21	Clapper Rail	9.45*	–	–	A	TRE
6/30/73	22	Clapper Rail	4.60*	–	–	A	TRE
6/30/73	23	Clapper Rail	1.75*	–	–	8	TRE
7/1/73	24	Clapper Rail	3.15*	–	–	–	LC
7/1/73	25	Clapper Rail	5.15*	–	–	A	LC
7/1/73	26	Clapper Rail	.91*	–	–	A	LC
7/1/73	27	Clapper Rail	.45*	–	–	A	LC
7/1/73	28	Clapper Rail	.25*	–	–	A	LC
7/1/73	29	Clapper Rail	.75*	–	–	A	LC
7/1/73	30	Clapper Rail	.23*	–	–	A	LC
7/1/73	31	Clapper Rail	.17*	–	–	A	LC
7/2/73	32	Clapper Rail	1.51*	–	–	A	TRB
7/2/73	33	Clapper Rail	1.02*	–	–	A	TRB
7/2/73	34	Clapper Rail	1.18*	–	–	A	TRB
6/13/73	35	Clapper Rail	1.48*	–	–	A	TRW
4/16/73	36	Clapper Rail	.62*	–	–	A	EBR
4/4/73	37	Clapper Rail	.61*	–	–	A	TRE
5/4/73	38	Clapper Rail	.72*	–	–	1	EBR
4/6/73	39	Clapper Rail	.93*	–	–	A	EBR
4/15/73	40	Clapper Rail	1.67*	–	–	A	EBR
3/6/73	41	Clapper Rail	2.60*	–	–	A	TRE
5/11/73	42	Clapper Rail	4.85*	–	–	A	TRW
9/7/73	43	Clapper Rail	.20*	.33	–	A	BM
9/7/73	44	Clapper Rail	.01*	.37	–	A	BM
9/7/73	45	Clapper Rail	.47*	1.23	–	A	BM
					Beak		
9/7/73	46	Clapper Rail	.10*	.43	1.66	A	BM
9/7/73	47	Clapper Rail	.13*	.54	–	A	BM

					Feather		
9/7/73	48	Clapper Rail	1.09*	2.44	15.3	A	JC
9/7/73	49	Clapper Rail	.24*	.50	–	A	JC
9/7/73	51	Clapper Rail	.18*	.41	–	A	LCI
9/7/73	52	Clapper Rail	.21*	.45	–	A	LCI
9/7/73	53	Clapper Rail	.23*	.53	–	A	LCI
9/7/73	54	Clapper Rail	.35*	.48	–	A	CI
9/7/73	55	Clapper Rail	1.5	4.16	–	A	CI
					Feather		
6/30/73	56	Clapper Rail	–	–	30.3	A	TRE
					Beak		
					8.1		
					Egg Shell		
6/30/73	57	Clapper Rail	–	–	.17	A	EBR
					Egg		
6/13/73	58	Clapper Rail	–	–	.20	A	EBR
10/71	59	Sora	2.15	12.08	–	A	TRE
4/4/73	60	Sora	.92	3.64	–	A	TRE
4/4/73	61	Sora	.38	1.54	–	A	TRE
4/4/73	62	Sora	1.83	4.00	–	A	TRE
4/4/73	63	Sora	2.39	5.64	–	A	TRE
4/4/73	64	Sora	.27	.69	–	A	TRE
3/6/73	65	Sora	.12	.46	–	A	TRE
3/9/73	66	Sora	.11	.52	–	A	EBR
3/6/73	67	Sora	1.28	1.67	–	A	TRE
2/15/73	68	Sora	–	.40	–	A	BI
5/11/73	69	Sora	–	.40	–	A	TRW
5/11/73	70	Sora	.37	1.42	–	A	TRW
4/4/73	71	Sora	.11	.40	–	A	TRE
6/12/73	72	King Rail	.12	–	–	A	BI
7/5/73	73	King Rail	.59	1.37	–	A	BI
6/12/73	74	King Rail	.84	2.26	–	A	BI
4/4/73	75	Virginia Rail	–	.40	–	A	BI

Table 2. Mercury Concentrations in Rail Roods (Fresh Wet Weight Basis).

Date	I.D.#	Species	Mercury Concentration (ppm.)	Location
10/71	901	Periwinkle Snail	2.58	TRE
10/71	902	Periwinkle Snail	4.00	TRE
10/71	903	Periwinkle Snail	4.65	TRE
10/71	904	Periwinkle Snail	1.19	TRE
10/71	905	Periwinkle Snail	1.39	TRE
10/71	906	Periwinkle Snail	1.27	TRE
7/5/73	907	Periwinkle Snail	.71	TRB
7/5/73	908	Periwinkle Snail	.90	TRB
7/1/73	909	Periwinkle Snail	1.84	EBR
5/11/73	910	Periwinkle Snail	1.63	TRW
7/1/73	911	Periwinkle Snail	.77	TRE
4/4/73	912	Periwinkle Snail	16.8	TRE
10/71	913	Fiddler Crab	.27	TRE
7/1/73	914	Fiddler Crab	.12	BI
7/1/73	915	Fiddler Crab	.12	EBR
7/1/73	916	Fiddler Crab	.27	TRE
6/10/73	917	Squareback Crab	.23	BI
7/1/73	918	Squareback Crab	.12	BI
7/1/73	919	Squareback Crab	.20	EBR

KEY TO ABBREVIATIONS

TRE = Turtle River East (A)
TRW = Turtle River West (B)
TRB = Turtle River-Brunswick (C)
EBR = East Brunswick River (D)
CI = Colonel's Island (E)
LCI = Little Cumberland Island (F)
JC = Jointer Creek (G)
BM = Belleville Marsh (H)
BI = Butler Island (I)
LC = Lazaretta Creek (J)

*Indicates Average Value of Duplicate Samples.

LITERATURE CITED

Bakir, F., S. Damluji, L. Amin-Zaki, M. Murtadha, J. Al-Rawi, S. Tikriti, H. Dhahir, T. Clarkston, J. Smith, R. Doherty. 1973. Science 181:230-240.

Borg, K., H. Wanntorp, K. Erne, et al. 1969. Aklymercury Poisoning in Terrestrial Swedish Wildlife, Viltrevy, 6:301-377.

Fimreite, N. 1970a. Effects of Dietary Methyl-mercury on Ring-Necked Pheasants, with Special Reference to Reproduction. Can. Wildl. Serv. Occas. paper #9.

Fimreite, N. and L. Karstad, 1971. Effects of Dietary Methyl-mercury on Red-tailed Hawks. The J. Wildl. Manage. 35(2):293-300.

Fimreite, N., W. H. Holsworth, J. A. keith, P. A. Pearce, and I. M. Bruchy. 1971. Mercury in Fish and Fish-eating Birds Near Sites of Industrial Contamination in Canada. The Can. Field Nat. 86:211-220.

Fyfe, R. 1971. Pesticides and Wildlife. Can. Wildl. Ser. 4-13.

Georgia Water Quality Control Board. 1971. Mercury Pollution Investigation in Georgia 1970-71. Atlanta, Ga. 116pp.

Gilchrist, C. 1973. Personal Communication. Virginia Comm. of Game and Island Fisheries. Toppahannock, Va.

Heinz, G. 1974. Effects of Low Dietary Levels of Methyl-mercury on Mallard Reproduction. Bull. Environ. Contam. Toxcial., 11(4):386-392.

Lambou, V. 1972. Problems of Mercury Emissions Into The Environment of the United States. U.S. E.P.A. 81pp.

Martin, A., H. Zim, and A. Nelson. 1951. American Wildlife and Plants. Dover Publ., Inc. New York, N.Y. 500pp.

Oney, J. 1954. Final Report Clapper Rail Survey and Investigation Study. Georgia Game and Fish Comm. Atlanta, Ga. 50pp.

Pierce, P., J. Thompson, W. Likosky, L. Nickey, W. Barthel, A. Hinman, 1972. Alkly Mercury Poisoning in Humans. J. Am. Med. Assoc. 220(11):1439-1442.

Subcommittee of the Comm. of Govt. Operations (Hearings) 1971. Mercury Pollution and Enforcement of the Refuse Act of 1899 (Part 1). U.S. Gov. Printing Office, Washington, D.C. 1089pp.

Study Group on Mercury Hazards. 1970. Hazards of Mercury. Special Report to the Secretary's Pesticide Advisory Comm. Dept. Health, Education and Welfare, and Environmental Protection Agency. 69pp.

Windom, H. 1972. Mercury Distribution in the Estuarine - Nearshore Environment. A.S.C.E. Natl. Water Resour. Eng. Meet. No. 1572. 14pp.

Zeller, H. and J. Finger. 1971. Investigations of Mercury Poisoning In The Aquatic Environment of the Southeastern United States. Presented at 10th Annual Environ. and Water Res. Conf. Vanderbilt Univ., Nashville, Tenn. 32pp.